

## CHAPTER I

---

### INTRODUCTION

---

---

---

---

Economic growth is a critical factor in determining living standards over the long term. Although much of the discussion about macroeconomic policy concerns the problem of minimizing short-term fluctuations in output, slight changes in growth rates over the long term will compound to swamp even the largest of cyclical slowdowns. The recession of 1981-1982, for example, witnessed the deepest decline in per capita output since World War II--nearly 5 percent from peak to trough. Although this seems large, it is dwarfed by the effects of the slowdown in growth that occurred during the 1970s. If the average rate of growth experienced from the end of the war to 1973 had been maintained during the 1973-1990 period, per capita output would have been 36 percent higher in 1993 than it turned out to be.

The relatively slow growth of real gross domestic product (GDP) in recent decades, at least compared with growth during the 1950s and 1960s, has spurred interest in federal policies that may promote long-run growth and higher living standards. The current concern about the level of the federal budget deficit stems primarily from its predicted effects on future living standards.

Can the federal government do anything to speed growth and raise living standards over the long term? Clearly, basic government services such as national security, protection of property rights, a justice system, and basic infrastructure are important because they provide the framework for economic activity. But the question remains: Does the government have a role in economic growth beyond providing these basic services?

For the past three decades, the standard tool for analyzing long-run growth has been the neoclassical model of economic growth. The model, however, is unable to analyze the effects of many changes in government policy; it simply lacks the mechanisms required to do so. The neoclassical theory implies that changes in the federal deficit will affect per capita GDP in the long run but that the effects will be relatively modest. According to the model, reducing the deficit will raise the level of national saving, permit more capital investment, and lead to higher living standards in the long run. However, increased national saving and capital investment will provide a one-time boost to the *level* of per capita output but will have no effect on the long-run rate of *growth* of per capita output. The model allows for an

increase in the rate of growth of per capita output only if the rate of technological advance increases.

This traditional view has been challenged in recent years by new models of economic growth that, on the surface, appear to fit the empirical evidence better. These models are collectively known as endogenous growth models because they imply perpetual growth in per capita output without relying on technological advances. In general, the new models suggest that policy changes, such as reducing the federal deficit, can have powerful effects on living standards in the long run. These effects are much larger than those the neoclassical model would predict, because they can affect not only the level but also the rate of growth of per capita output.

In addition, many of the new models contain a fuller set of mechanisms for studying the effects of changes in government policy. Some models suggest that taxes should provide incentives to invest in physical capital, whereas others suggest that taxes should favor investment in human capital.<sup>1</sup> Several analysts show that in some situations, government interventions--taxes or subsidies--are not only effective but desirable. The models also open up new avenues for studying how policies on international trade affect economic growth.

The challenge presented by the new models of economic growth has stimulated a round of empirical work evaluating the neoclassical model. Most of the evidence, though still accumulating, generally supports the neoclassical model's assumptions and predictions. However, the empirical evidence indicates that several concepts stressed in the literature on endogenous growth are also important, particularly issues related to human capital.

One promising approach is to incorporate human capital into the neoclassical model, which now includes only physical capital. This addition allows the model to account for many of the empirical anomalies for which it has been criticized. In addition, the literature on endogenous growth may prove useful in understanding the sources of technological progress--a major source of growth that the neoclassical model does not explain. The two frameworks should not be viewed as separate choices; instead, analysts can use elements from each to examine different aspects of the process of long-run economic growth. Further research is required to reconcile the subtle differences between the two.

---

1. In this paper, human capital refers to the level of education, skills, or training in a person or in society. A more complete definition would include health or any other resource embodied in people. See G.S. Becker, *Human Capital* (Chicago: University of Chicago Press, 1975).

## **CHAPTER II**

---

### **THE NEOCLASSICAL MODEL OF ECONOMIC GROWTH**

---

---

---

The neoclassical model of economic growth dates back to the mid-1950s and the work of Robert Solow.<sup>1</sup> That work, which earned Solow a Nobel Prize, established the theoretical framework for nearly all studies of long-run economic growth for the next 30 years. Using a few basic assumptions, Solow demonstrated that in the long run an economy would tend toward an equilibrium marked by continual growth of output. This equilibrium, known as a steady state, is characterized by constant levels of capital per worker and output per worker.

#### **ASSUMPTIONS OF THE NEOCLASSICAL MODEL**

---

Solow's model incorporates several simplifying assumptions.

- o The economy's rate of national saving and rate of growth of the labor force are both exogenous (unaffected by other variables explained by the model) and constant.
- o The economy is in equilibrium (that is, at full employment).
- o Output is produced using two factors--labor and capital--and a neoclassical production function determines how they are combined to produce output.

The neoclassical model also makes three important assumptions about the production function. The first assumption concerns a characteristic of the production function--returns to scale. That term refers to the additional output produced as a result of an increase in all factors of production. The neoclassical model assumes that the production function displays constant returns to scale--that is, a given percentage increase in both capital and labor will yield the same percentage increase in output. For example, doubling the amount of labor and capital used in production would also double the resulting level of output. This assumption is usually justified with an

---

1. The seminal paper is R.M. Solow, "A Contribution to the Theory of Economic Growth," *Quarterly Journal of Economics*, vol. 70 (February 1956), pp. 65-94. See also T. Swan, "Economic Growth and Capital Accumulation," *The Economic Record*, vol. 32 (1956), pp. 334-361; or D. Cass, "Optimum Growth in an Aggregative Model of Capital Accumulation," *Review of Economic Studies*, vol. 32 (July 1965), pp. 233-240.

argument about replication: a firm that owns a plant that produces \$10 million of output each year could in principle produce \$20 million by building a second, identical plant next to the first.

Other production functions might be characterized by decreasing or increasing returns to scale. Decreasing returns occur if doubling all inputs to production results in a less-than-doubling of output--for instance, if the second plant in the above example added less than \$10 million to output. Increasing returns to scale occur if doubling the inputs yields more than twice as much output.

Second, the model assumes that the production function displays decreasing returns to each input--that is, successive additions of labor or capital (holding the other constant) will yield progressively smaller increments of output. Economists refer to this phenomenon as a declining marginal product of labor or capital. This assumption is particularly important with regard to physical capital. If investment in capital goods is characterized by decreasing returns, then each additional investment project will yield a smaller gain in output than the one before it. In other words, as more and more capital is added to a fixed supply of labor, the additional output that results diminishes steadily.

The third assumption is that markets for goods and inputs have minimal imperfections. This assumption ensures that competition drives down product prices to equal marginal cost, workers' real wages equal the marginal productivity of labor, and the rental rate on capital equipment equals the marginal product of capital. If market imperfections are minimal, researchers can compute the contributions of each input to the growth of output and determine the most important sources of growth, a process known as growth accounting.

## **IMPLICATIONS OF THE NEOCLASSICAL MODEL**

---

Several implications follow from the assumptions of the neoclassical model. The most important--an economy that grows at a constant rate--is so ingrained and familiar that it might be taken for granted. Other implications are more subtle, but they all can be examined empirically to evaluate the validity of the model. This section discusses the results of the model that are relevant to the theory of endogenous growth and the evaluation of empirical evidence that follows.

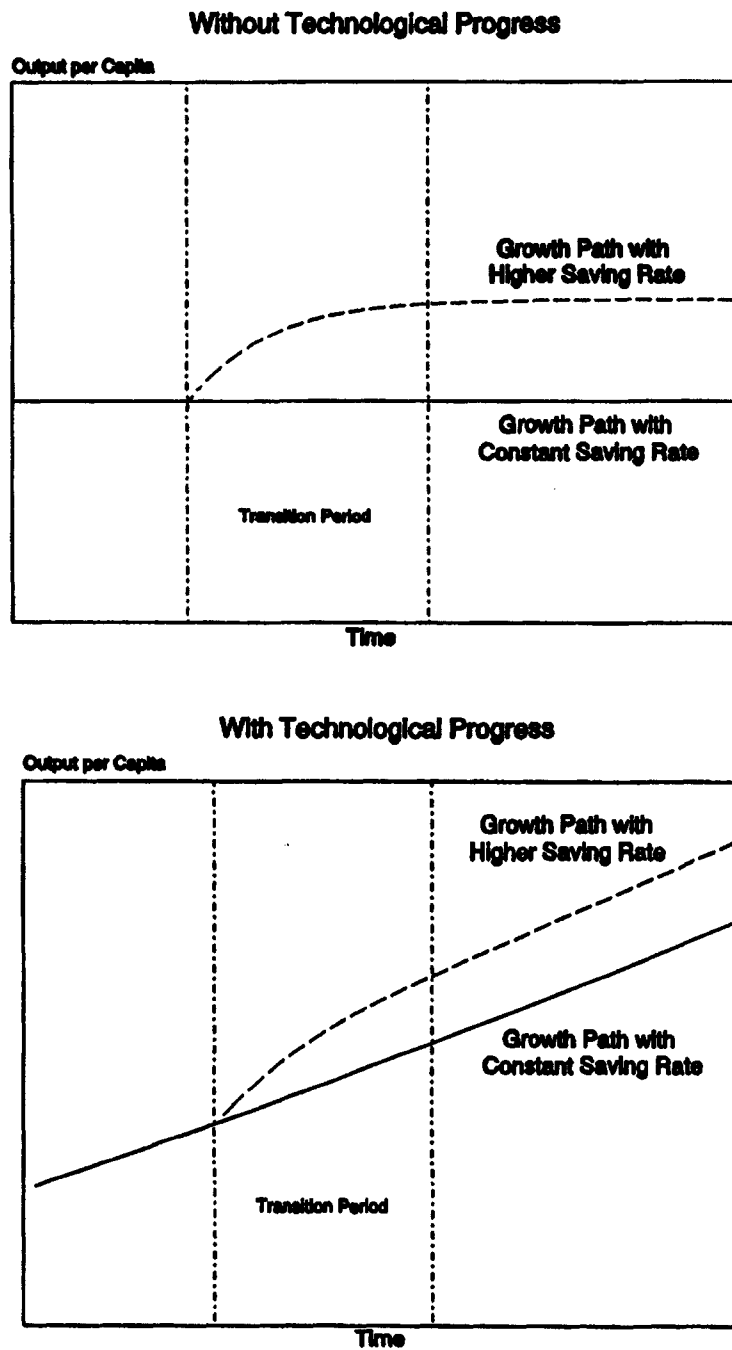
### **Existence of a Stable Equilibrium with Growth of Per Capita Output**

The most important result of the neoclassical model of economic growth is that, in the long run, output grows at a constant rate; that is, the economy reaches a steady state. However, in that simple model, the rate of growth is limited to the rate of growth of the labor force, which means that the model cannot explain long-run growth in output per worker--a crude measure of the standard of living. Further, although a change in an economy's saving rate can affect the level of per capita output, it will have no effect on the economy's steady-state rate of growth (see Figure 1). A permanent increase in the rate of national saving will raise the level of per capita output but will not affect the rate of growth once the economy has reached the new steady state. Of course, during the transition to the new, higher level of per capita output, the economy's growth rate is higher than it would have been otherwise. Estimates of the length of this transition period range from 15 to 40 years.

In order to explain the growth of per capita output over long periods, the neoclassical model introduces the idea of technological progress. In long-run equilibrium, per capita output can grow only if the economy's productive processes are augmented with new technology that produces additional output without additional inputs. If that occurs, then output can expand in the absence of any change in employment or the capital stock. This implication is crucial to the neoclassical model of long-run economic growth; the only source of growth in per capita output is exogenous technological progress (see Figure 1). More important, the model has little to say about the factors that determine the rate of technological change; it instead assumes that the growth of technological change is determined exogenously (in particular, that it has nothing to do with the rate of saving or investment). Therefore, the model provides little assistance to those who want to analyze growth of per capita output.

The model's assumption of diminishing returns to each input ensures that output per worker does not grow in the absence of technological progress. Intuitively, this assumption means that as each new investment project is pursued, the return from that investment (namely, the increase in output and revenues) is lower than that from the previous investment. Investing will be worthwhile for a firm as long as the return from doing so is greater than the cost of capital. At some point, the return from successive investment projects will be driven down to the cost of capital, and further investment (above what is required to replace worn-out capital) will no longer be profitable. The firm

**FIGURE 1. EFFECTS OF AN INCREASE IN THE SAVING RATE IN THE NEOCLASSICAL MODEL OF ECONOMIC GROWTH, WITH AND WITHOUT TECHNOLOGICAL PROGRESS**



SOURCE: Congressional Budget Office.

will not undertake subsequent investment projects, thus leaving constant the amount of capital per worker and the amount of output produced per worker. If the returns to successive investment projects did not fall, it would always be profitable to invest, capital accumulation would continue perpetually, and per capita output would continue to rise.

### Convergence of Economies with Different Starting Levels of Per Capita Output

A second implication of the neoclassical model is known as convergence, or catch-up—a process by which economies with initially low levels of per capita output (poor countries) grow faster than those with initially higher levels (rich countries). The neoclassical model predicts that poor countries will eventually catch up to the rich countries and that the per capita output of both will end up at the same level and rate of growth. This prediction is conditional; it hinges on the assumption that the economies are identical in every respect except for their initial level of per capita output. In particular, the model assumes that the economies have identical production technologies, saving rates, institutional frameworks (for example, legal systems and property rights), and so forth.

Per capita output converges in the neoclassical model because of decreasing returns to capital. The model predicts that an economy with a lower level of capital per worker will have a higher marginal product of capital. Therefore, a poor country should have a higher marginal product of capital than a rich country because it, by definition, has lower levels of output and capital per worker. Thus, if the two countries have identical rates of saving, then the poorer country will grow faster because each additional dollar of investment will produce more goods and services than in the richer country. The model also predicts that investment in a poor country will exceed its pool of savings because the high rate of return on physical capital will attract flows of investment funds from rich countries, speeding the process of convergence.

Relaxing the assumption that all economies have identical production technologies produces another source of convergence. The spread of technology from industrialized countries to developing countries can cause the latter to grow faster. The neoclassical model attributes this growth to technological progress. The theory can accommodate the transfer of technology but does not necessarily predict that it will occur.

### Falling Rate of Return on Investment

The neoclassical model also implies that the rate of return on investment (crudely, the profit rate) will fall over time as the level of capital per worker rises toward the steady state. Profits fall because the rate of return to owners of capital varies directly with the marginal productivity of capital. As the amount of capital available to workers in the economy increases, the profit rate decreases as a result of diminishing returns to capital. This assertion is quite simple theoretically but is extremely difficult to verify empirically because the concepts involved--particularly capital itself--are so difficult to measure. In addition, growth resulting from technical progress can mask the effects of a declining profit rate.

### LIMITATIONS OF THE NEOCLASSICAL MODEL

Authors who write about endogenous growth have cited several shortcomings of the neoclassical model as the primary motivation for developing their models. The first and most serious limitation of the neoclassical model is that it relies on technological progress to drive growth in per capita output. Instead of explaining the sources of technological change, the model assumes it will occur independent of the factors considered by the model.<sup>2</sup> Yet history is characterized by sustained growth in per capita output over long periods, with no evidence of a persistent decline. The neoclassical model therefore fails to explain what is arguably the most important source of growth--technological change.

Second, the neoclassical model provides only a rudimentary framework for analyzing the effects of government policy on economic growth. The model lacks any explicit channels through which the government can permanently raise the rate of growth of per capita output (except policies that speed up technological progress). The answer to the question of whether policy affects growth is not immediately obvious, but that question cannot be asked, much less answered, within the confines of the neoclassical model. Changes in government policy, however, clearly affect the decisions that workers, managers, and investors make every day. Having a theory of long-run growth

---

2. Although Solow and others later extended the basic neoclassical model to explain the growth in technical change, none were able to provide a complete theory of the source of technical change. See R.M. Solow, "Investment and Technical Progress," in K.J. Arrow, S. Karlin, and P. Suppes, eds., *Mathematical Methods in the Social Sciences* (Stanford, Calif.: Stanford University Press, 1960). See also H. Uzawa, "Optimum Technical Change in an Aggregative Model of Economic Growth," *International Economic Review*, vol. 6 (January 1965), pp. 18-31; and D.W. Jorgenson and F. Griliches, "The Explanation of Productivity Change," *Review of Economic Studies*, vol. 34 (July 1967), pp. 249-283.

that could be used to analyze the effects of such changes would therefore be desirable.

Although the neoclassical theory is well equipped to analyze the effects of at least one policy change--namely, lowering the federal deficit--it predicts that deficit reduction will have a relatively weak impact on output. The Congressional Budget Office (CBO) estimates that each percentage point of permanent increase in the ratio of national saving to gross domestic product would, in the long run, permanently raise consumption by about 1 percent above what it would have been without the increase in saving.<sup>3</sup> But in order to raise national saving by 1 percent of GDP, the deficit must be reduced by a greater amount, perhaps as much as 3 percent of GDP. The greater reduction is required because lowering the federal deficit seems likely to spur a drop in private saving and foreign borrowing. If so, then the increase in funds available for private investment will be smaller than the amount by which the deficit is reduced.

Third, the model contains only a few tools for analyzing how policies that expand (or contract) the volume of international trade affect growth. Studies of international trade in the neoclassical tradition have demonstrated that the liberalization of trade yields one-shot gains that result from reallocating resources to more productive uses. In addition, empirical evidence indicates that countries with an outward orientation tend to grow faster than those that adopt a more protectionist stance. The missing link is a theoretical demonstration of beneficial effects on the rate of growth (rather than merely on the level of output) stemming from more liberal trade policies.

## GROWTH ACCOUNTING

---

After Solow devised his model of economic growth, other economists developed a method to estimate the contributions of the factor inputs (labor and capital) to the growth of output. Early efforts discovered that an alarmingly large fraction of growth--over 40 percent, by some estimates--went unexplained by the inputs and had to be attributed to technological progress.<sup>4</sup>

---

3. See Congressional Budget Office, *The Economic and Budget Outlook: Fiscal Years 1994-1998* (January 1993), Chapter 5.

4. See E.F. Denison, *Why Growth Rates Differ: Postwar Experience in Nine Western Countries* (Washington, D.C.: Brookings Institution, 1967). For more details about growth accounting, see E.F. Denison, *Trends in American Economic Growth, 1929-1982* (Washington, D.C.: Brookings Institution, 1985); A. Maddison, "Growth and Slowdown in Advanced Capitalist Economies: Techniques of Quantitative Assessment," *Journal of Economic Literature*, vol. 25, no. 2 (June 1987), pp. 649-698; or D.W. Jorgenson, F. Gollop, and B. Fraumeni, *Productivity*

This finding raised the question: How good can the neoclassical theory be if it explains only 60 percent of the growth of output? Subsequent refinements to the method of accounting for growth have reduced the proportion of unexplained growth, thereby diminishing the impact of this critique and providing more support for the neoclassical model.

The assumptions of the neoclassical model make it easy to account for the growth of output in terms of the growth of the factor inputs. The assumption of perfect competition, in particular, aids in the accounting process by easing the computation of output elasticities of labor and capital. An output elasticity measures the percentage change in output that would result from a 1 percent change in one of the inputs. Under the model's assumptions, these elasticities can be approximated by the shares of labor compensation and capital income in the value of output. For example, payments to owners of capital in the United States are roughly 30 percent of total income, which means that the elasticity of output with respect to capital is 0.3. Therefore, a 10 percent boost in the capital stock leads to a 3 percent increase in the level of output.

Once the elasticities have been computed, one can account for the separate contributions of labor and capital to the growth of output over a given period by weighting the growth of each input by its output elasticity. Table 1 illustrates such an exercise using data collected by the Bureau of Labor Statistics (BLS) for the nonfarm business sector in the United States. It shows the proportion of the growth of output that can be explained by the growth of the factor inputs, once each has been weighted by its output elasticity. During the 1948-1990 period, for example, 33 percent of the growth in output resulted from an expansion of hours worked (labor) and 34 percent from increased capital services. Growth in multifactor productivity--a measure of the joint productivity of labor and capital--must account for all remaining growth in output because it is computed as a residual. It is, by definition, the portion of growth in output that is unexplained by the growth of labor and capital.

On average, only 68 percent of the growth in output over the postwar period can be explained by the growth of labor and capital. This finding demonstrates a gap in the neoclassical theory; the remaining growth is assumed to occur as a result of technological progress (as measured by multi-

**TABLE 1. ILLUSTRATION OF ACCOUNTING FOR GROWTH IN THE PRIVATE NONFARM BUSINESS SECTOR (In percent)**

Period	Average Annual Rate of Growth				Contribution to the Growth of Output <sup>b</sup>		
	Output	Labor <sup>a</sup>	Capital	MFP	Labor <sup>a</sup>	Capital	MFP
1948-1990	3.6	1.7	4.1	1.1	33	34	32
1948-1960	3.5	1.1	3.5	1.6	22	30	46
1960-1973	4.7	1.8	4.6	2.1	26	29	44
1973-1990	2.7	2.0	3.2	0.1	53	46	2

**SOURCES:** Congressional Budget Office using data from the Bureau of Labor Statistics.

**NOTES:** Dates correspond to peaks in the business cycle, as measured by the National Bureau of Economic Research.

MFP = multifactor productivity.

- a. Measured as an index of hours worked, adjusted for changes in workers' levels of education and experience.
- b. Calculated as the growth of each factor input (weighted by its output elasticity) and of multifactor productivity as a percentage of the growth of output. The calculations assume that labor's output elasticity is 0.7 and capital's output elasticity is 0.3.

factor productivity) and is not attributed to economic forces in the standard theory. One goal of growth accounting is to improve the estimates of labor and capital in order to reduce the role of multifactor productivity. If a more sophisticated accounting raises the contribution of labor and capital, then the contribution of multifactor productivity will fall. This drop is important because it reduces the proportion of growth that is not explained by the theory and may indicate that a larger proportion of growth can be directly affected by government policies, such as reducing the deficit.

To some degree, the estimate formed by BLS has already reduced the contribution of multifactor productivity. The series that BLS uses for the capital and labor inputs are not, as one might expect, simply the stock of capital and the number of hours worked. Rather, they are both indexes designed to capture the different levels of productivity inherent in different types of capital goods and in workers with different levels of education and experience.

BLS's capital input is an index designed to measure the flow of capital services that derives from a given stock of capital. When constructing this index, each type of capital asset (for example, producers' durable equipment, structures, inventories, and land) is weighted according to its level of productivity, which permits a more accurate accounting for growth. If, for example, a dollar of investment spending shifted to a more productive type of capital, this series would grow faster, but a series based on the capital stock would not. A method of accounting for growth that used the series in Table 1 would, correctly, attribute the increased production to the capital input, but one that was based on the capital stock would attribute the added output instead to multifactor productivity, giving a misleading view of the role of technological progress in fostering growth.

In fact, investment spending in the United States has shifted toward assets with higher marginal productivity during the past two decades; the share of investment devoted to equipment has risen while the share going to structures has declined, and a larger share of equipment purchases has been devoted to computers. If the capital input is measured using the capital stock instead of capital services, some of the growth in output caused by this shift will be attributed mistakenly to technological progress.<sup>5</sup>

To compute the labor input, BLS disaggregates hours worked into subcategories that differ according to sex, education, and work experience. It then weights each category by the corresponding rate of hourly earnings to adjust each type of labor by its level of productivity. If employers decide to substitute more productive labor for less productive labor (for example, experienced workers for youths), production can increase without any change in hours worked. A measure of labor based on hours worked will not capture the increase in effective labor, but BLS's will. Dale Jorgenson, who has done a similar disaggregation, estimates that the increase in hours worked accounts for about two-thirds of the growth of the labor input and that one-third stems from improvements in the productivity of labor resulting from substitutions among different types of labor.<sup>6</sup>

---

5. Dale Jorgenson estimates that using the capital stock instead of capital services would capture only 20 percent of the growth of the capital input. See D.W. Jorgenson, "Productivity and Economic Growth," in E.R. Berndt and J.E. Triplett, eds., *Fifty Years of Economic Measurement: The Jubilee of the Conference on Research in Income and Wealth* (Chicago: University of Chicago Press, 1990).

6. For more details, see Jorgenson, "Productivity and Economic Growth"; D.W. Jorgenson, "Comments and Discussion" [on Baily and Schultze], *Brookings Papers on Economic Activity: Microeconomics* (1990), pp. 407-412; or Jorgenson, Gollop, and Fraumeni, *Productivity and U.S. Economic Growth*.